Representation of Climate Impacts in GCAM
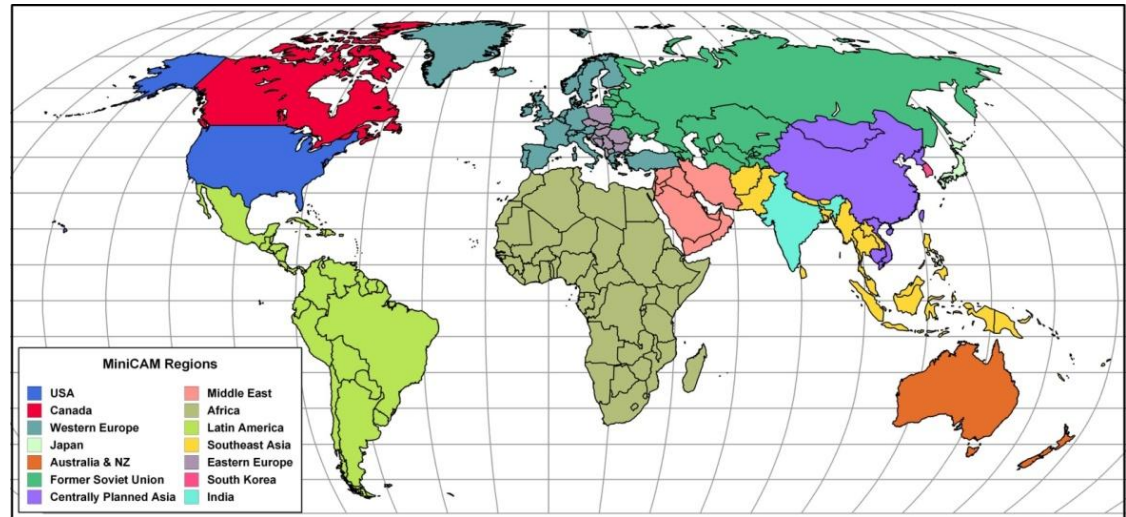
Leon Clarke

Workshop on Modeling Climate Change Impacts and Associated Economic Damages
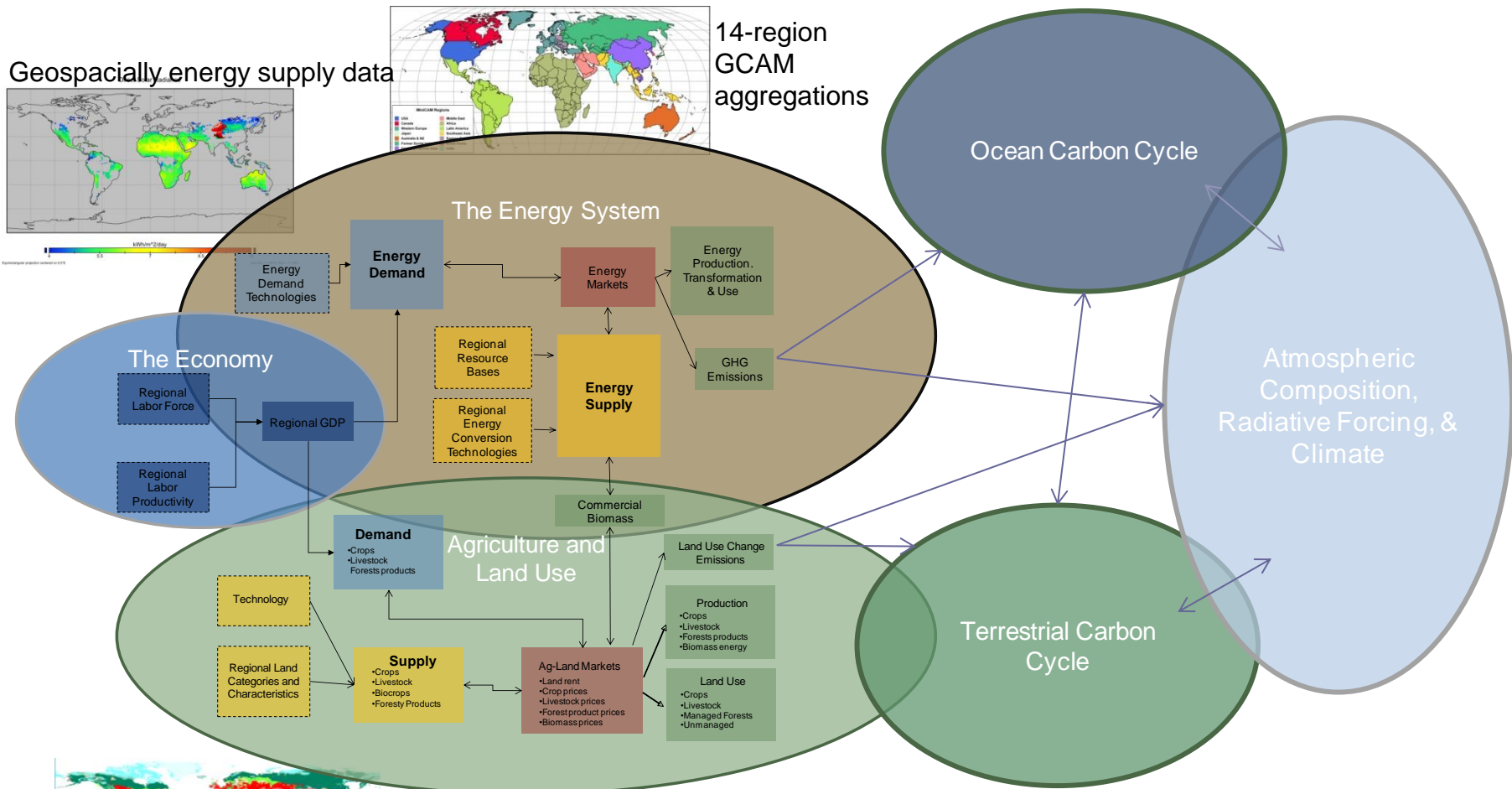
Washington DC

Thursday, November 18, 2010

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What is GCAM?

MiniCAM Regions
- USA
- Canada
- Western Europe
- Japan
- Australia & NZ
- Former Soviet Union
- Centrally Planned Asia
- Middle East
- Africa
- Latin America
- Southeast Asia
- Eastern Europe
- South Korea
- India

► Builds on the energy/economy model of Edmonds and Reilly completed three decades ago.

► Combines economics-based energy, agricultural models with an Integrated Climate Assessment Model (MAGICC).

► Dynamic-recursive model.

► Technologically detailed integrated assessment model.

► 14 geopolitical regions

► Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonacious aerosols, reactive gases, sulfur dioxide.

► Runs through 2095 in 15-year time steps (moving to variable time steps).

Geospacially energy supply data

14-region GCAM aggregations

Ocean Carbon Cycle

Atmospheric Composition, Radiative Forcing, & Climate

The Energy System

| Energy Demand Technologies | **Energy Demand** | | Energy Markets | Energy Production, Transformation & Use |

Regional Resource Bases

Energy Supply

GHG Emissions

The Economy

Regional Labor Force

Regional GDP

Regional Labor Productivity

Regional Energy Conversion Technologies

Commercial Biomass

Agriculture and Land Use

Demand
•Crops
•Livestock
•Forests products

Technology

Regional Land Categories and Characteristics

Supply
•Crops
•Livestock
•Biocrops
•Foresty Products

Ag-Land Markets
•Land rent
•Crop prices
•Livestock prices
•Forest product prices
•Biomass prices

Land Use Change Emissions

Production
•Crops
•Livestock
•Forests products
•Biomass energy

Land Use
•Crops
•Livestock
•Managed Forests
•Unmanaged

Terrestrial Carbon Cycle

Geospacially explicit land use data

GCAM

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3

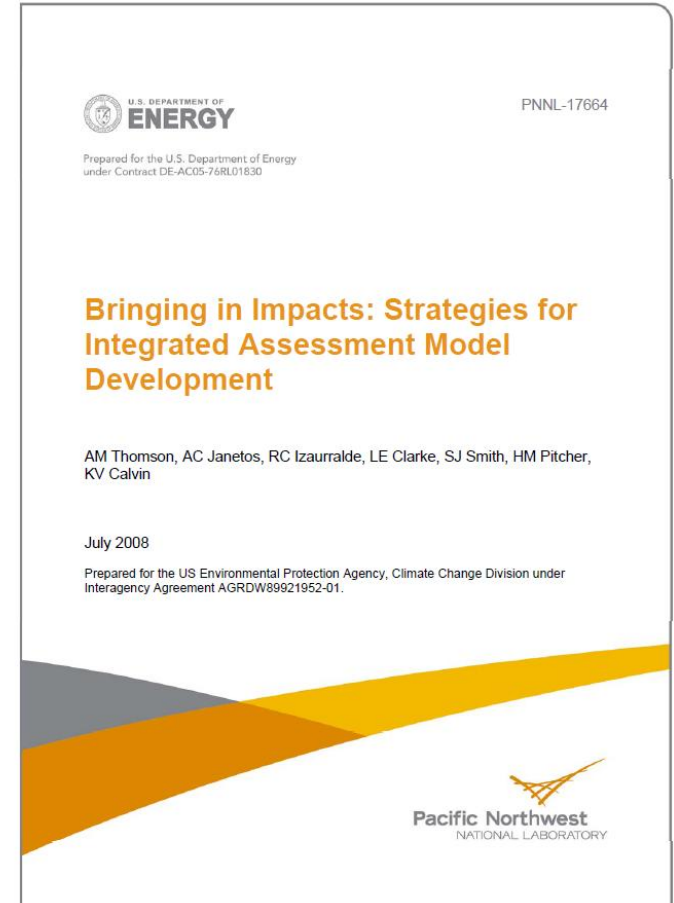# What impacts would we want to consider in PNNL/JGCRI IA modeling?

▶ Goal #1: Pick things that are important.

▶ Goal #2: Pick things that involve interactions among the various systems represented in IA models

▶ Goal #3: Pick things that we actually have a chance of doing.

▶ Expanding on #3: A primary benefit of IA models is their ability capture interactions between systems. This leads to a perspective on impacts in which we distinguish between

■ Those which are most amenable to an integrated perspective.

■ Those which can "hang" off of the model and not feed back to other systems in the model.

▶ Although integrated analysis brings impacts together in an integrated system, aggregating and monetizing all impacts is not inherently core to considering impacts in GCAM.

A Plan for Impacts in PNNL/JGCRI's IA Modeling

▶ Near-term priorities;

- Agriculture, Forestry, Land Use and Land Cover
- Energy Use
- Ocean Acidification

▶ High priorities with substantial model development necessary

- Water Resources
- Sea-Level Rise and Coastal Impacts
- Human Health and Demographics

▶ Of substantial interest, but not easily quantifiable within existing IA models

- Extreme Events and Thresholds
- Biodiversity

U.S. DEPARTMENT OF
ENERGY

PNNL-17664

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Bringing in Impacts: Strategies for Integrated Assessment Model Development

AM Thomson, AC Janetos, RC Izaurralde, LE Clarke, SJ Smith, HM Pitcher, KV Calvin

July 2008

Prepared for the US Environmental Protection Agency, Climate Change Division under Interagency Agreement AGRDW89921952-01.

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A Plan for Impacts in PNNL/JGCRI's IA Modeling

▶ There are many ways to pursue these impacts:

- One dimension
  - All in GCAM.
  - Linkages to other models (iESM, regional initiatives).
- Another dimension
  - Endogenous interactions within the model – feedbacks with other systems.
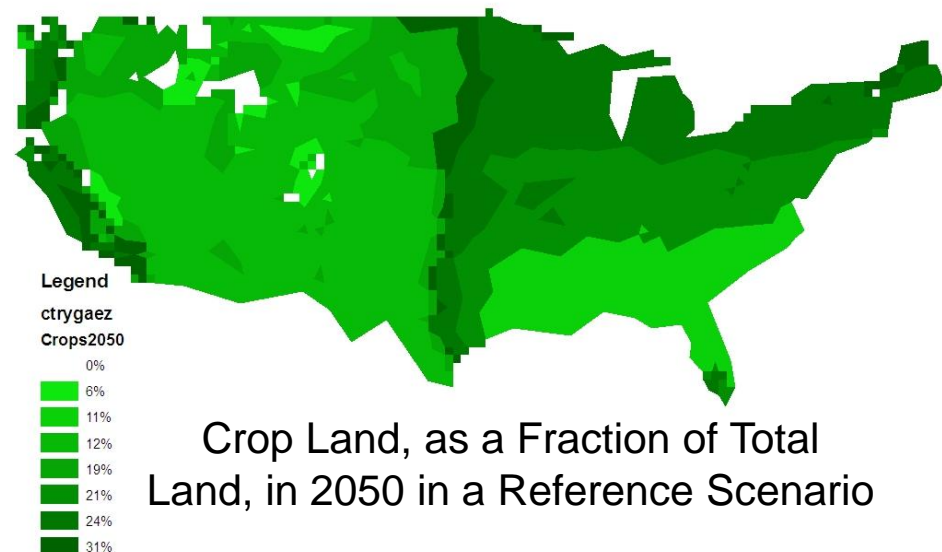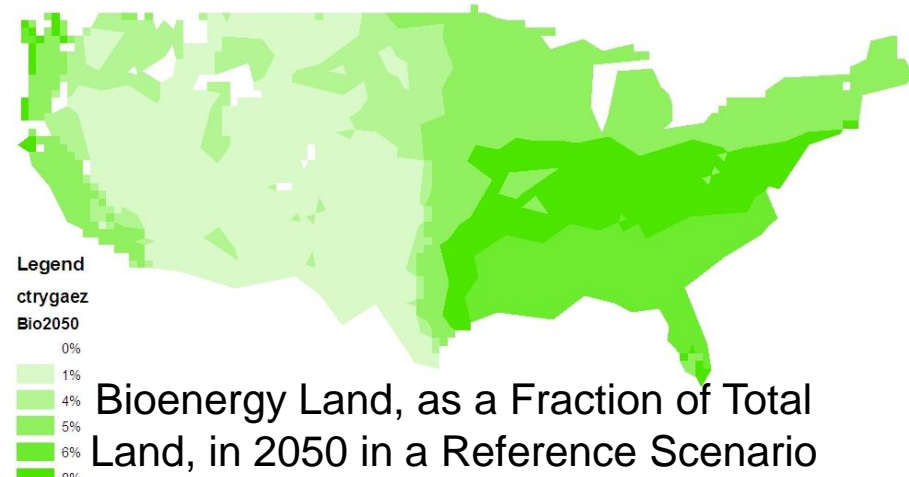 - "Hanging" off of GCAM.

U.S. DEPARTMENT OF **ENERGY**

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Bringing in Impacts: Strategies for Integrated Assessment Model Development

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Land Use Impacts

GCAM Moving to an Agro Ecological Zone Formulation for AgLU

OPTIONS FOR FEEDBACK

▶ Link results from ecosystem models (EPIC/BIOME/CENTURY) and ESMs to GCAM by changing parameters.

▶ Use sensitivity studies to begin to develop a concept of the scale of impacts in the context of integrated assessment and adjust GCAM parameters.

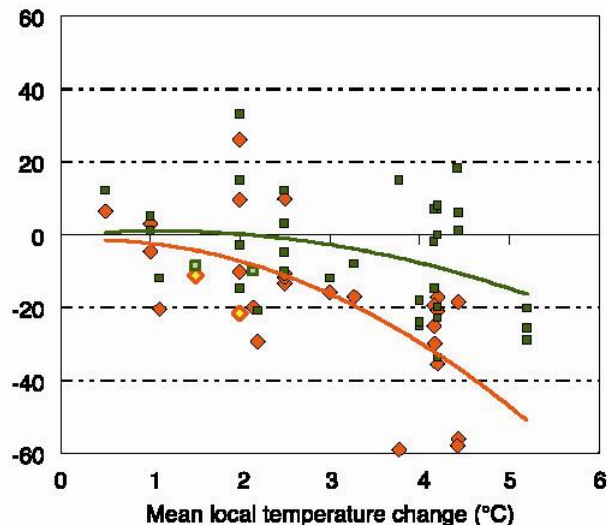▶ Develop a reduced-form representation of ecosystem processes and response to climate change in GCAM.

Legend
ctrygaez
Bio2050
- 0%
- 1%
- 4%
- 5%
- 6%
- 8%

Bioenergy Land, as a Fraction of Total Land, in 2050 in a Reference Scenario

Legend
ctrygaez
Crops2050
- 0%
- 6%
- 11%
- 12%
- 19%
- 21%
- 24%
- 31%

Crop Land, as a Fraction of Total Land, in 2050 in a Reference Scenario

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8

Synthesis of process-level impact studies

(a) Maize, mid- to high-latitude
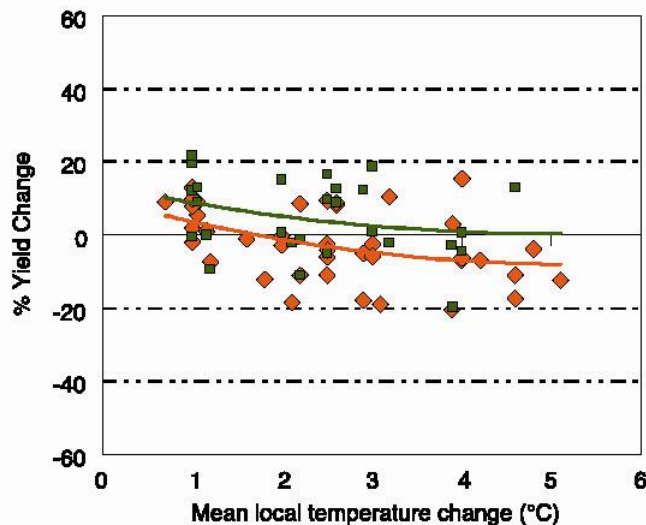
(b) Maize, low latitude

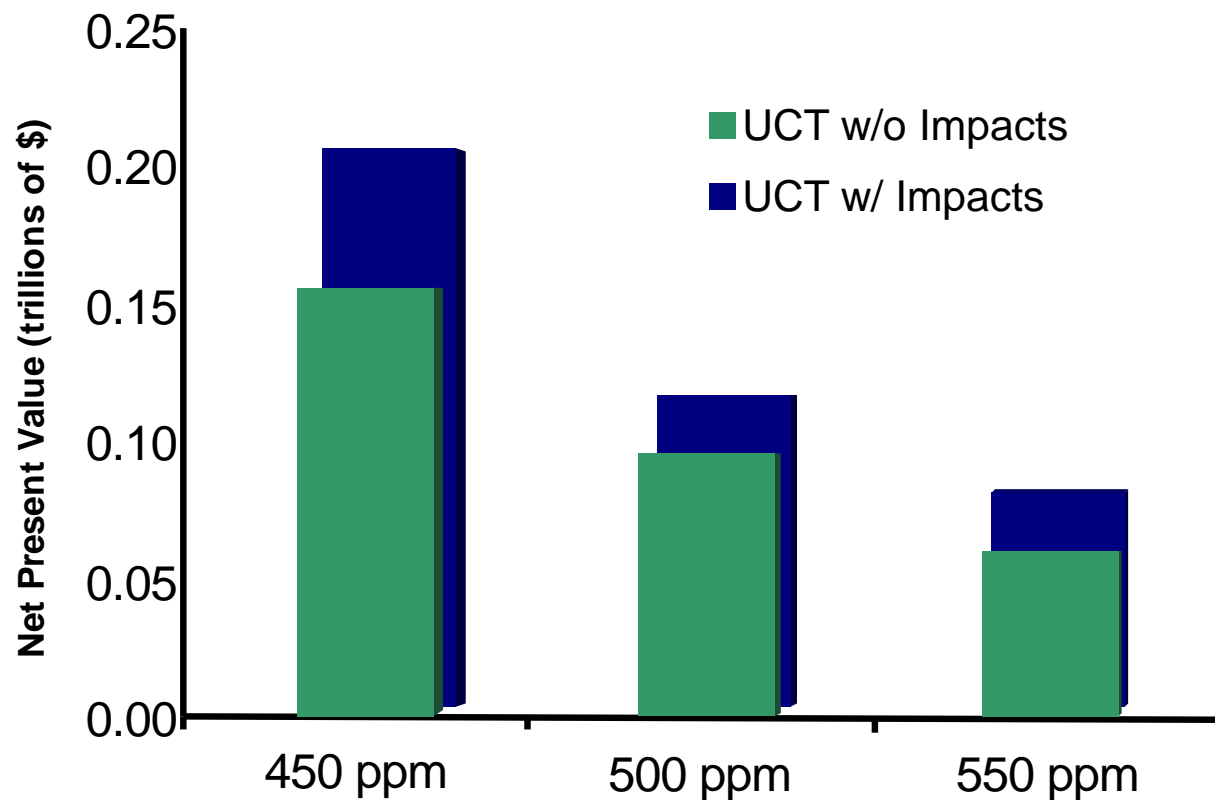(c) Wheat, mid- to high-latitude
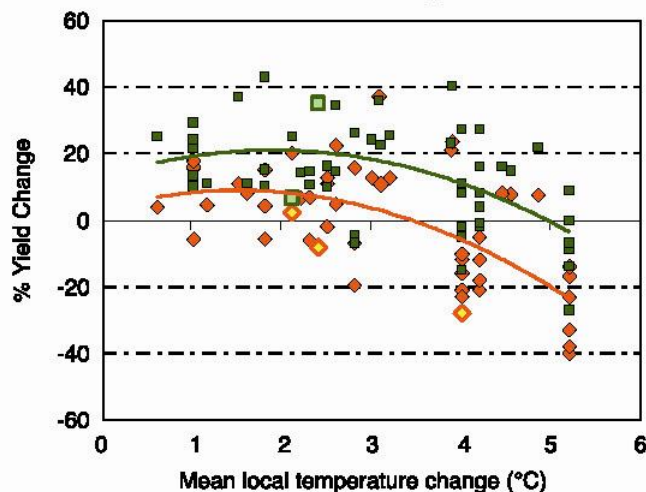
(d) Wheat, low latitude
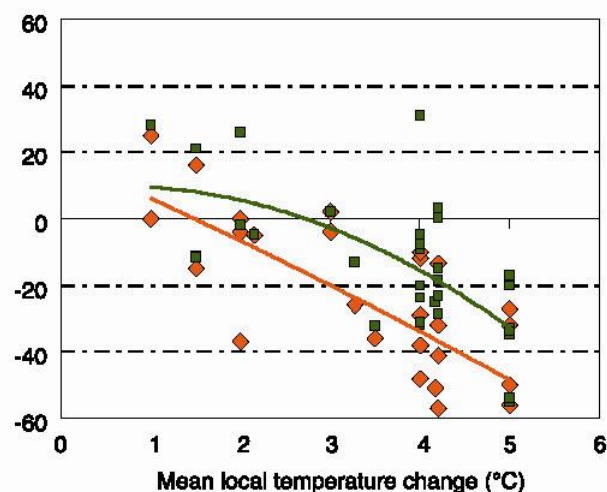
Climate impacts interact with mitigation policy.
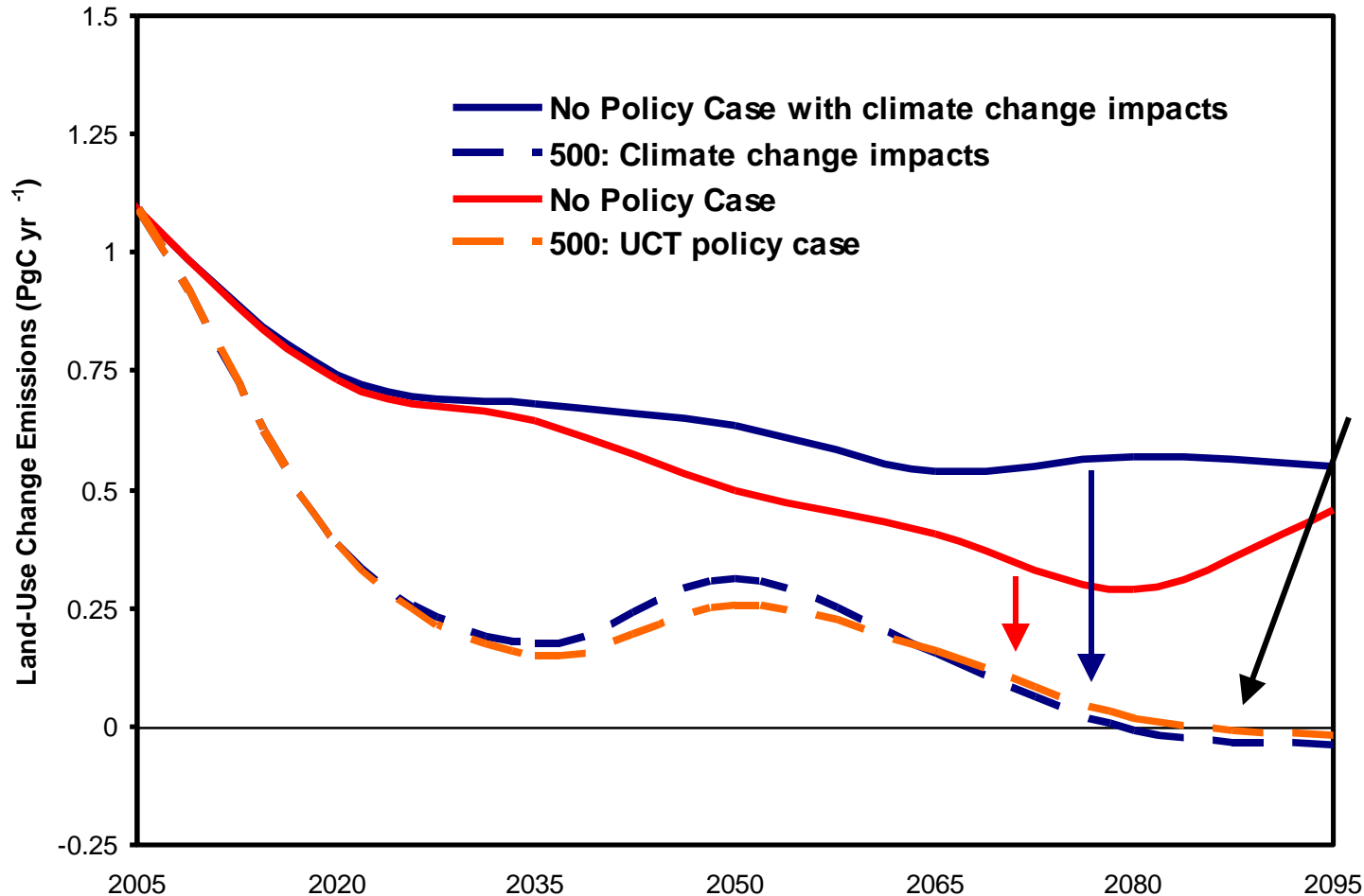
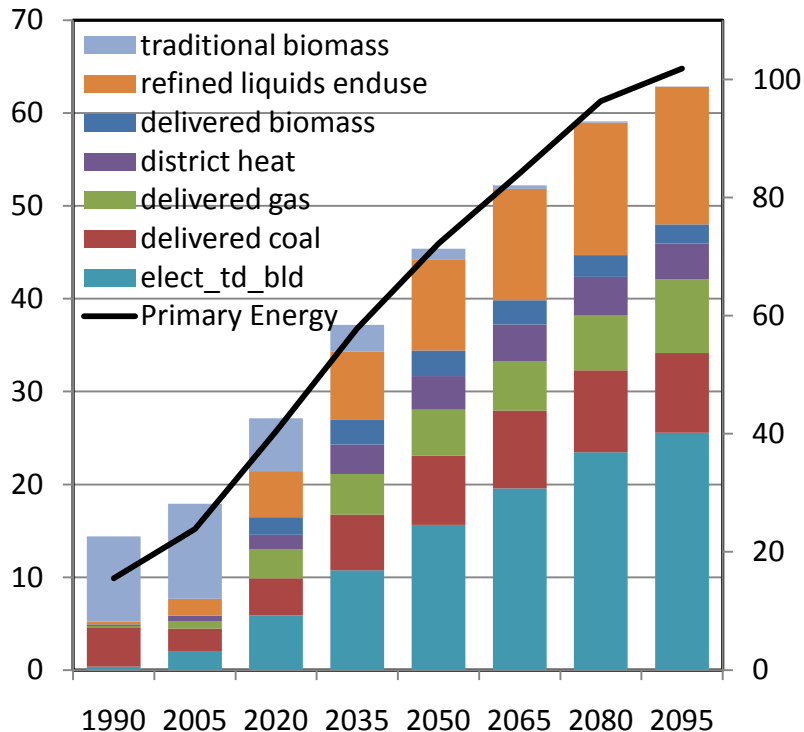By 2095, ILUC emissions go below 0 with climate policy cases
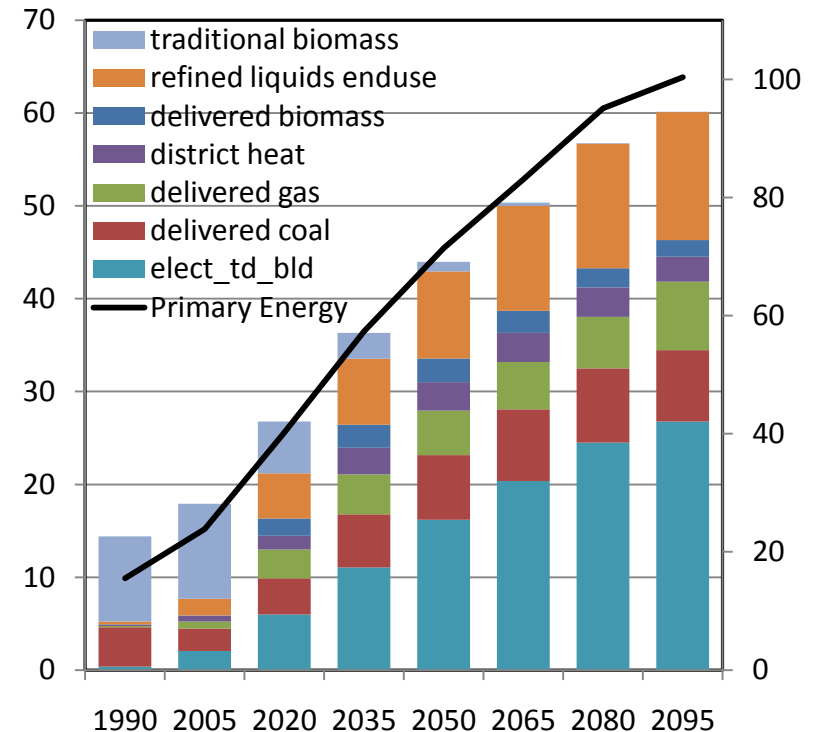
Impact of Impacts on Costs of Mitigation

Energy Impacts

Effects of Changing Degree Days on Building Energy Consumption:
The Reference Case of China Buildings

Fixed HDD of 2158
Fixed CDD of 1046

HDD decreasing from 2158 to 1458
CDD increasing from 1046 to 1746

Other Long-Term Options: (1) Feedbacks on power plant efficiencies, (2) Feedbacks on water supply for hydroelectric power.
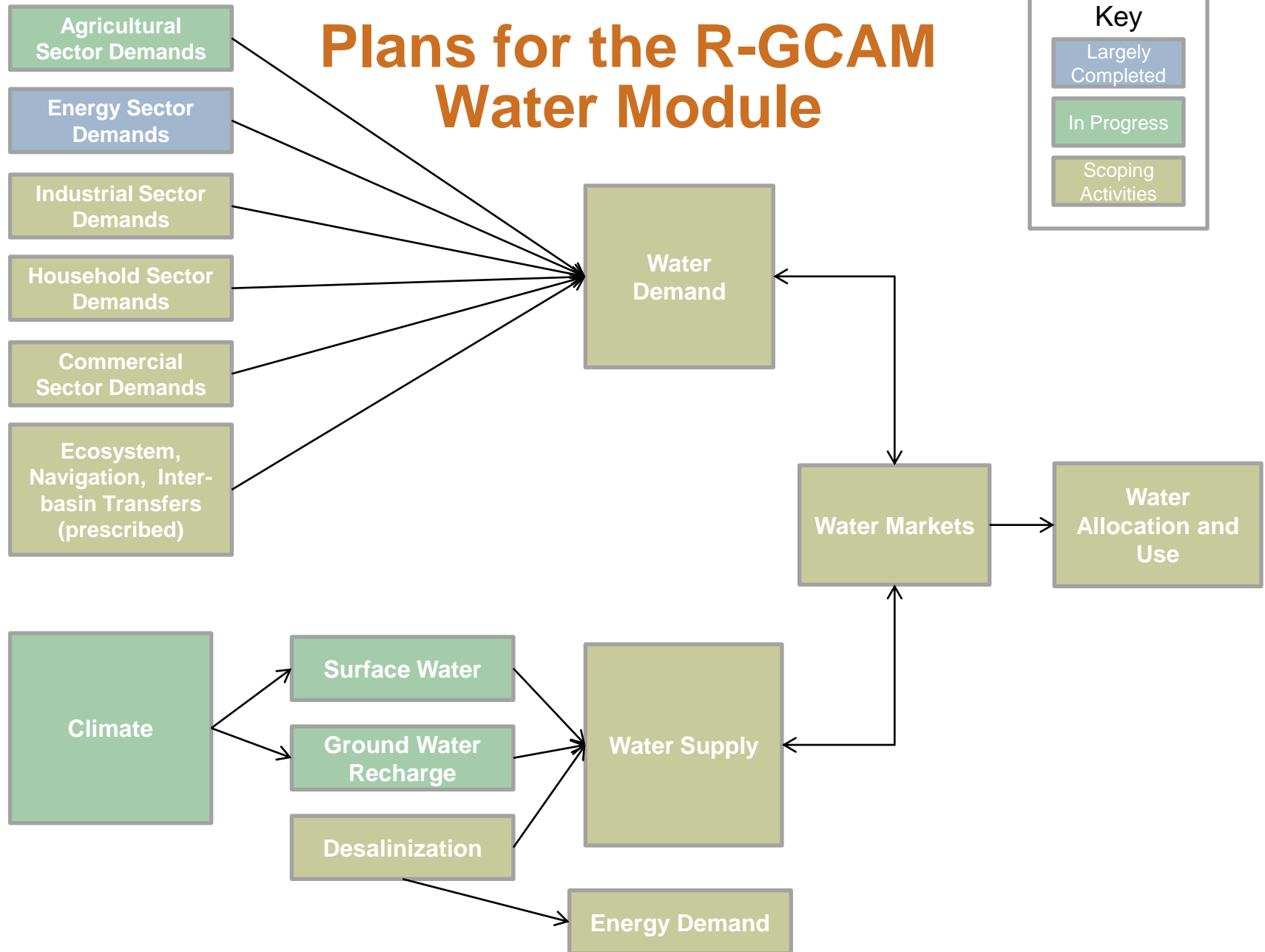
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Water

Plans for the R-GCAM Water Module

GCAM: U.S. Energy System Results

Withdrawals - no policy
gas, coal, nuclear, electricity w/CCS, electricity

Consumption - no policy
gas, coal, nuclear, electricity w/CCS, electricity

Withdrawals - 515ppm policy
gas, coal, nuclear, electricity w/CCS, electricity

Consumption - 515ppm policy
gas, coal, nuclear, electricity w/CCS, electricity
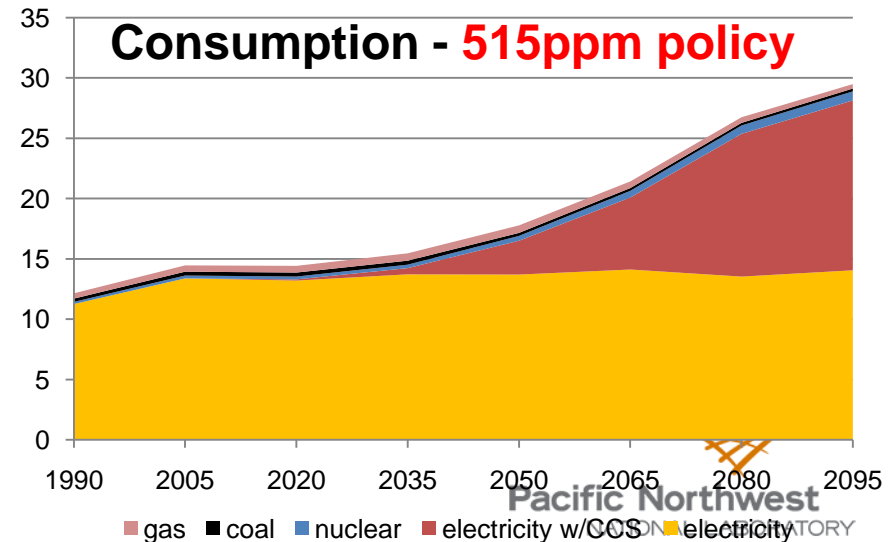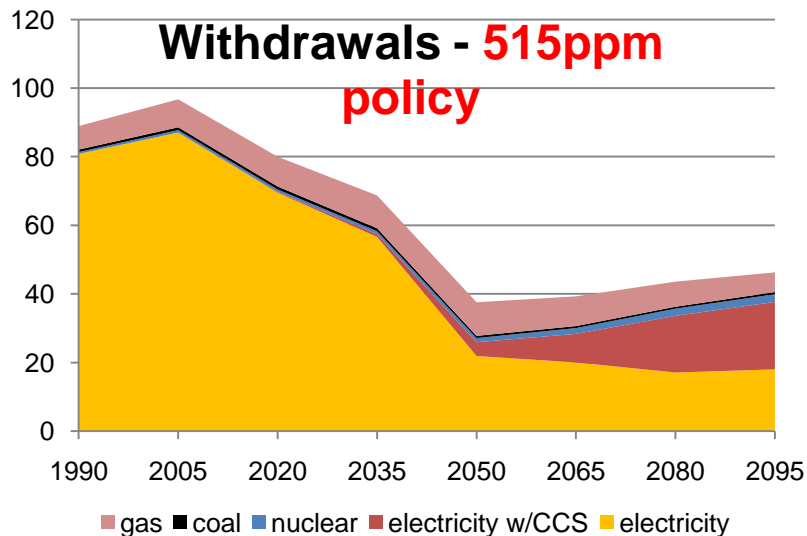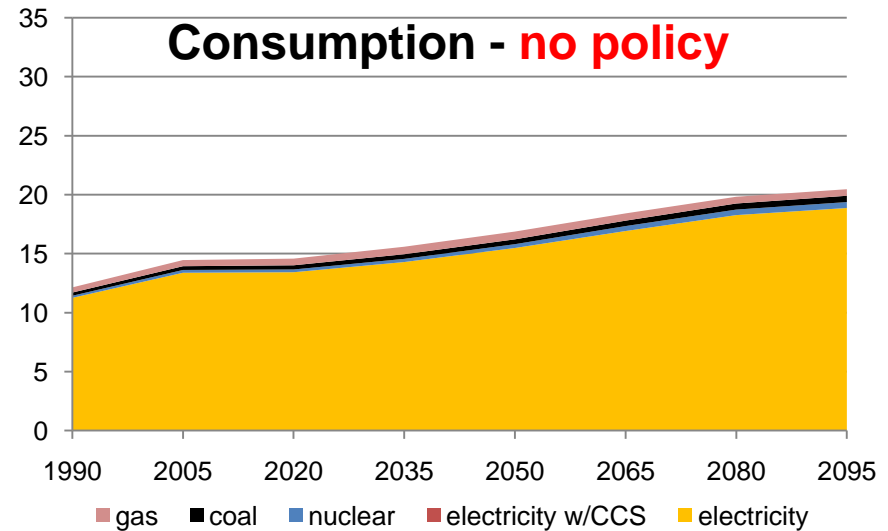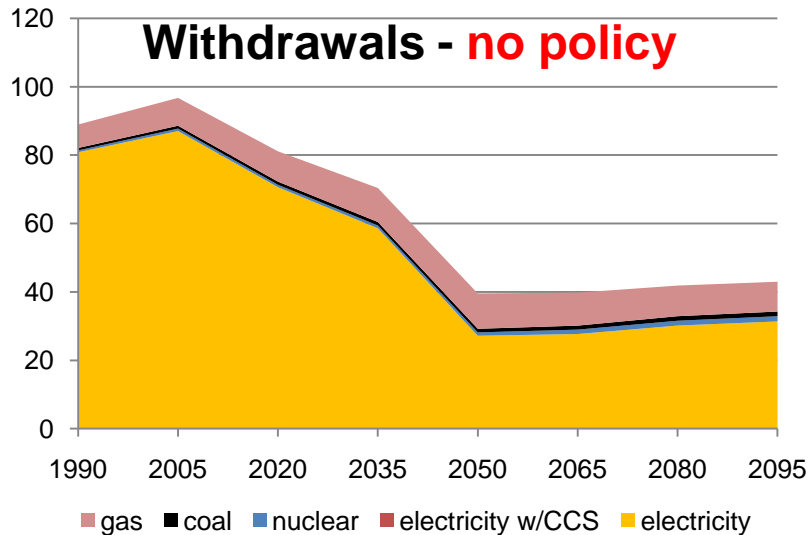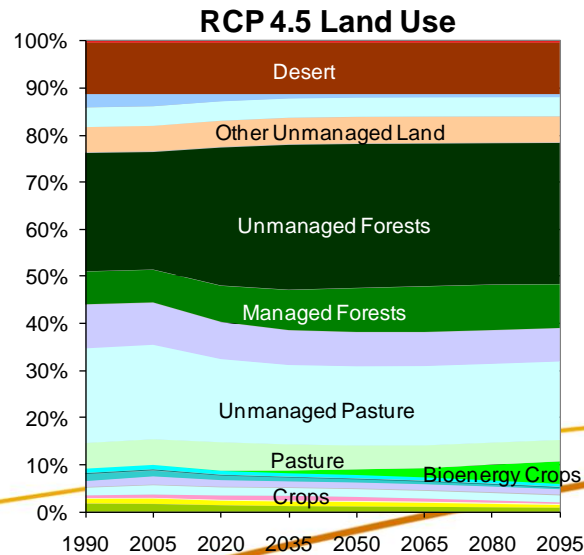
Examples of Linkages between Platforms: iESM

A Research Collaboration Between Three National Laboratories: PNNL, ORNL and LBNL

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Improving the Representations of Human-Earth System Interactions

Principal Investigators:
James A. Edmonds, Ph.D., Pacific Northwest National Laboratory (Lead)
John B. Drake, Ph.D., Oak Ridge National Laboratory
William D. Collins, Ph.D., Lawrence Berkeley National Laboratory

February 2009
Revised May 2009 per client request

Proposal to the U.S. Department of Energy, Office of Science
Climate and Environmental Sciences Division

Climate Change Modeling LAB 09-06
Strengthening the Coupling Between Climate and
Earth System Models (ESM) and Integrated Assessment Models (IAM)

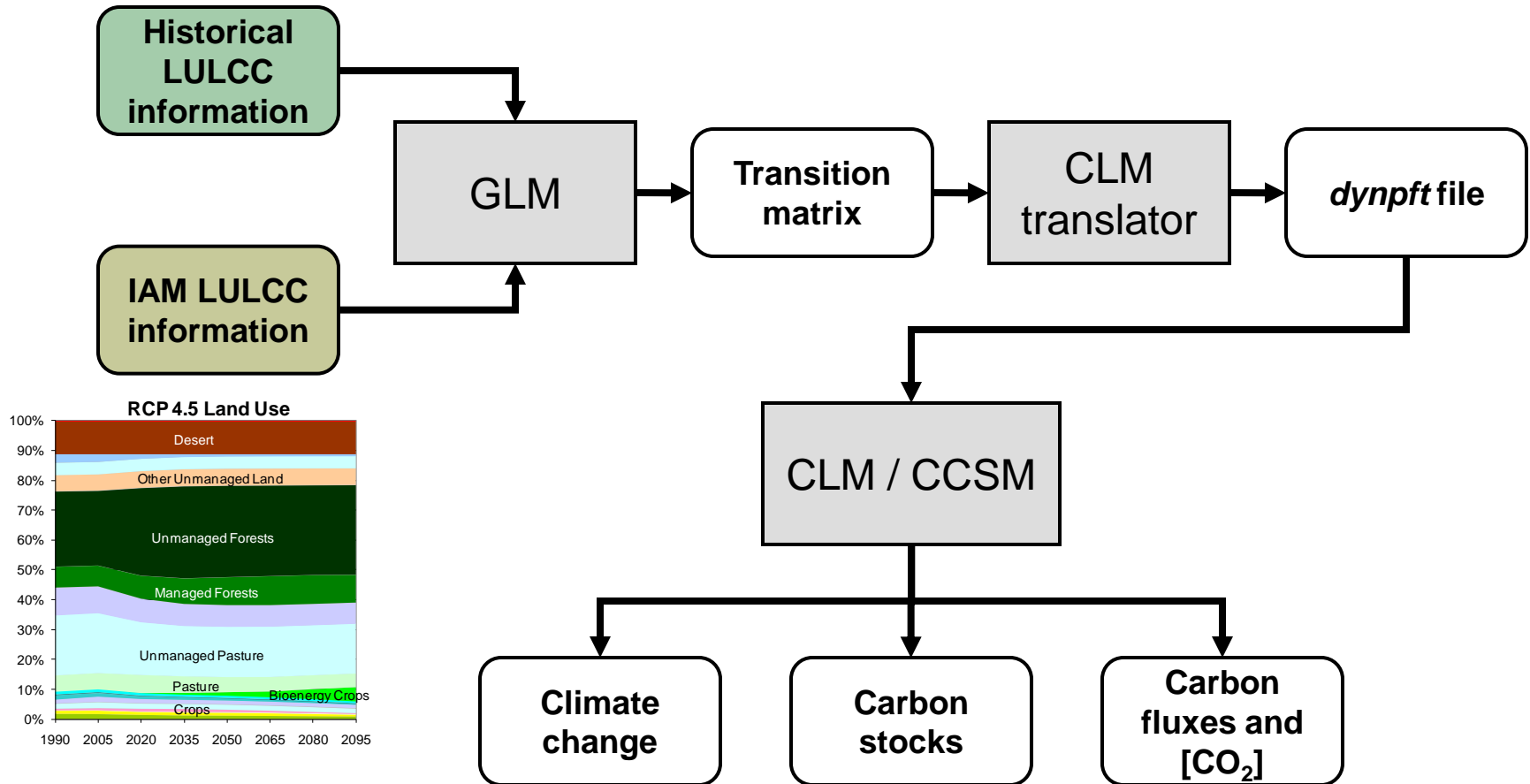Pacific Northwest
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Three Primary Tasks

► **Create a first generation integrated Earth System Model (iESM)** with both the human components of an IAM and a physical ESM;

► Further **develop components and linkages** within the iESM and apply the model to improve our understanding of the coupled physical, ecological, and human system;

► **Add realistic hydrology**, including freshwater demand, allocations, and demands to hold stocks of water as well as representations of freshwater availability from surface water, ground water, and desalinization

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iESM Phase 1 Initial Coupling Strategy

iESM Control (RCP 4.5)

GCAM → LULCC → CLM/CCSM

GCAM → Fossil fuel emissions → CLM/CCSM

Total Radiative Forcing

- A1FI
- A2
- B2
- B1
- RCP8.5
- RCP6.0
- RCP4.5
- RCP2.6

(W/m²)

2000 2020 2040 2060 2080 2100

RCP 4.5 Land Use

Desert

Other Unmanaged Land

Unmanaged Forests

Managed Forests

Unmanaged Pasture

Pasture

Bioenergy Crops

Crops

1990 2005 2020 2035 2050 2065 2080 2095
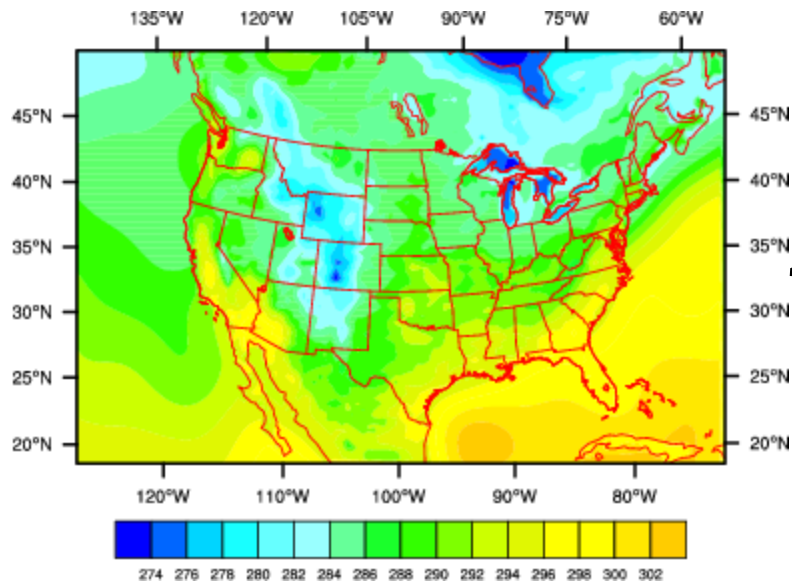
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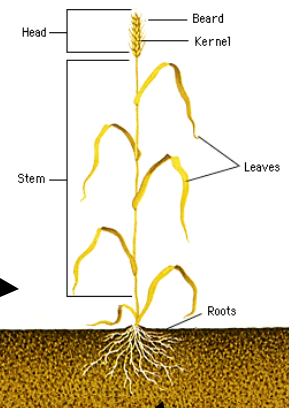# THE CLM: Initial One-way Coupling: Land Use and Land Cover Change (iESM Control experiment)

iESM multi-phase coupling strategy
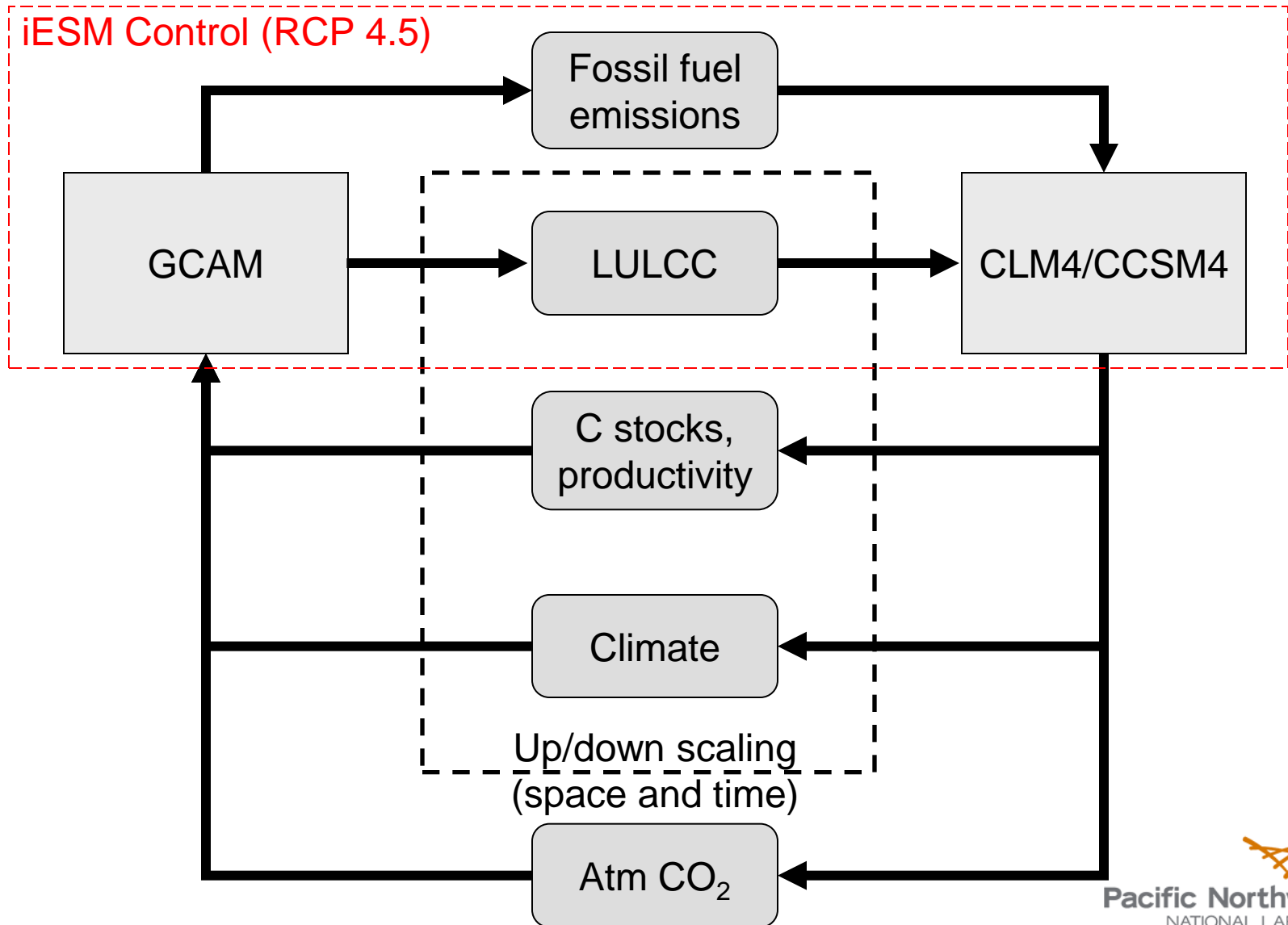
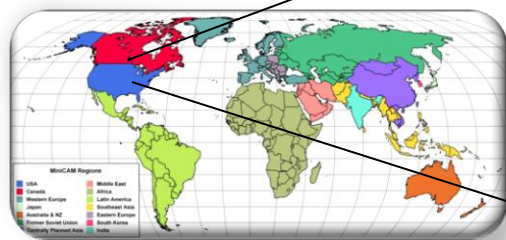# Examples of Linkages between Platforms: Regional Initiative

Regional Climate Model
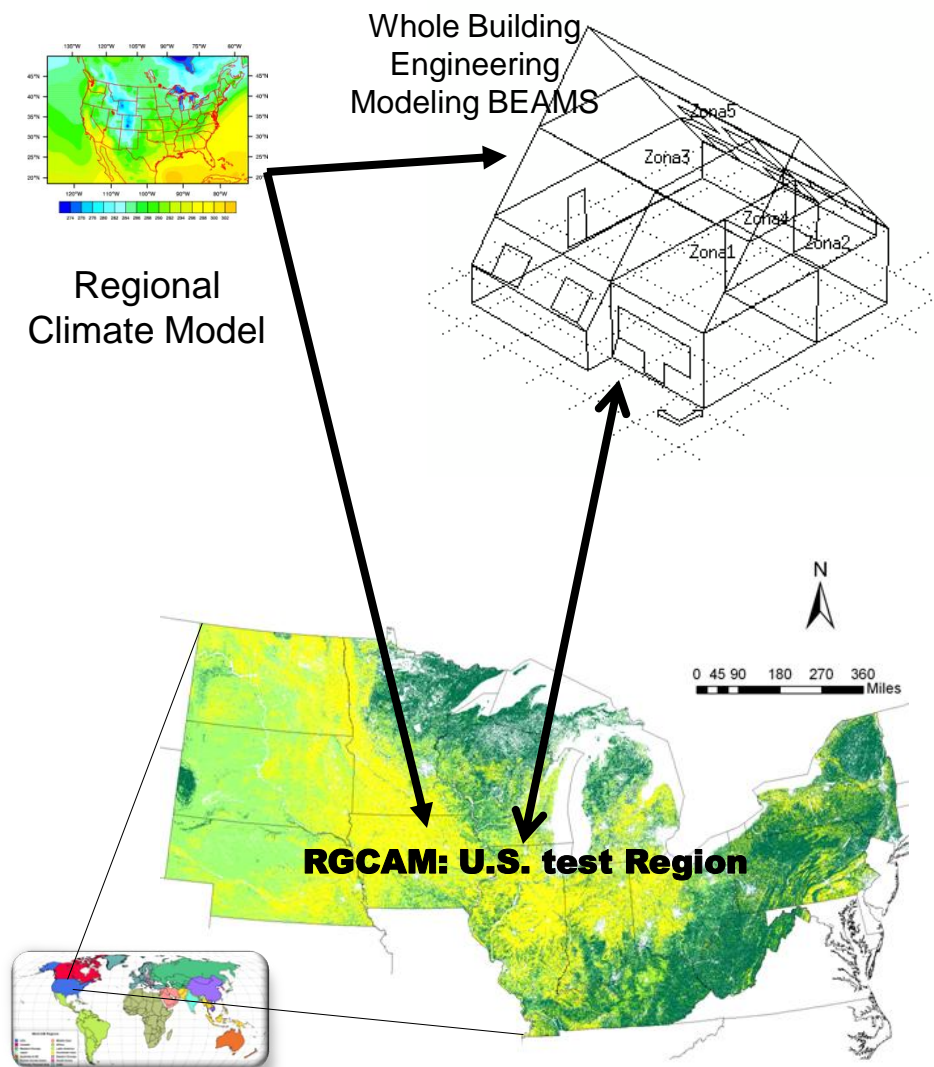
EPIC crop model

Major Land Cover in the 14 States

0 45 90   180   270   360
Miles

RGCAM: U.S. test Region

Legend
Field Crops
Herbaceous Vegetation
Woody Vegetation

23

Buildings Demand Modeling

Regional Climate Model

Whole Building Engineering Modeling BEAMS

RGCAM: U.S. test Region

BEND Model

► ~4000 buildings will be simulated in EnergyPlus to represent the buildings in the RGCAM U.S. test region:

- 4 climate zones
- 11 commercial building types
- 3 residential building types
- 6-9 sizes within each building type
- 7-8 vintages of existing buildings and 3 vintages of new buildings

► Building characteristic vary for each combination of attributes

► Hourly (8760 hours) electrical output used to calibrate models and determine building weights based on actual weather and actual hourly electric consumption for test region.

► Our challenge is to pass data back and forth between BEAMS and R-GCAM.

Discussion

Evergreen

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